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Patient Dose Estimation during Radiological X-Ray Procedures of Lower Extremities

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Abstract: The use of X-ray to investigate the lower extremities plays an important role in the health system of the country. During these radiological procedures a significant amount of radiation dose received by the patients' organs in most cases the skin organ that must be assessed to prevent patient from danger of radiation such as Cancer. The purpose of this research is to estimate the radiation doses received by the patients undergoing lower extremities x-ray examinations. The study was conducted in Kebbi State's referral hospitals such as Sir Yahaya Memorial Hospital [SMH] and Federal Medical Centre [FMC] for the period of six month in order to determine the radiation dose received during lower extremities radiographic examination, covering a sample of 150 patients. The exposure factors such as kilovolt (kV), exposure time product (mAs), Film Focus Distance (FFD), Focus to Skin Distance (FSD) and patient's age were recorded in the data collection form designed and entered into excel spreadsheet. Entrance Skin Dose was calculated using Mathematical expression incorporated into excels spreadsheet. The mean exposure parameters and ESD were estimated using statistical software. The mean ESD values calculated were used for determination of diagnostic reference level for all procedures. Inter-centre comparisons were performed and found that, the SMH results are significantly higher than FMC as a result of variation in exposure factors. The ESD results were well compared with other studies and found to be higher remarkably in some examinations. The diagnostic reference level results were obtained and compared between two centers but found to be higher in SMH than in FMC. The inconsistency in selecting exposure factors for same procedure in the two centers may lead to the over exposure of patients unnecessarily. Therefore, there is need for justification and optimization of some radiological procedures performed in the two centers.

Keywords: Lower extremities, Entrance Skin Dose, and Exposure parameters

1. Introduction

Different scholars who have carried out investigations have reported large differences in radiation doses received by the patients during specific X-ray procedures. Recently, these differences in patient dosimetric quantities observed in many countries have drawn the attention of researchers in patient doses worldwide (Mohamed, 2010). The urgent need for dose estimation due to radiological x-ray procedures has been identified by the expanding knowledge of the menace

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associated with low ionizing radiation doses (Mohamed, 2010). Relatively high values of radiation exposure have been considered a necessary consequence of lower extremities procedures (Mohamed, 2010). Since the early 2000s, the use of diagnostic medical imaging has grown rapidly and continues to grow. Despite the importance of lower extremity medical imaging in assisting physicians with diagnosis and treatment, the radiation exposure may increase patients' risk of cancer. Concerns about these negative effects have prompted international organizations to launch initiatives to reduce unnecessary radiation exposure from medical imaging. Such initiatives aim to improve patient safety by reducing radiation doses and demonstrating that imaging the lower extremities will benefit the patient more than harm. Despite such efforts, public concern about radiation exposure persists (Blaine et al, 2019).

The main risk in medical X-ray procedures is ionizing radiation exposure. Exposures were typically caused by improper equipment use and high exposure factors. The disparity in dose standards for exposure for the same medical examination is reason enough to call attention to this issue. These exposures can cause serious injuries and even cancer. Radiological imaging is commonly used to assess internal injuries or various disorders in patients' bodies (Samaila and Bello, 2021a). There are numerous risks associated with radiation exposure, including acute radiation injury and cancer effects. At high doses, the acute effects include organ damage, which can result in death. Because of their low energy, most radiographic investigations do not result in acute injuries to patients (less than 10 mGy). Cancer and genetic disorders are among the long-term effects of radiation. Radiation doses from lower extremity radiological procedures have been measured all over the world. The majority of rapidly evolving innovations have been paired with digital radiography (DR) units (Samaila and Bello, 2021a).

The lower extremities X-ray Procedure is the plain radiographic investigation of the arms, legs, hands, foot and ankle etc (Murphy and Glick, 2022). It is used to evaluate bone injuries such as fractures or broken bones (John, 2022). It can also reveal evidence of other injuries or conditions, such as infection, arthritis, tendinitis, bone spurs, foreign bodies, tumours, or birth defects, and it can be used to monitor bone growth and development in children (John, 2022). The procedure made numerous advancements in the last 25 to 30 years and allows rapid, noninvasive, high-resolution depiction of anatomy and pathology in the body (Imran, 2022). The main purpose of this study is to determine amount of radiation received by the patients regarding the radiation exposure associated with lower extremities imaging.

2. Material and Method

This study involved patients undergoing lower extremities (foot, ankle, & leg) radiographic examinations in the radiology department at Federal Medical Centre and Sir Yahaya Memorial Hospital. The two X-ray units included in the study had an average workload of more than 100 patients per week. The radiographic equipment used in SHM was Shimadzu Mobile X-ray imaging system with model number: collimator R-20CA, while in FMC was Mobile X-ray with model number: 2185226. Both have a total filtration of 3.0 mm Al for both inherent and added filters. A single exposure control system was available for use in the under-table or vertical position (Samaila and Bello, 2021a). The exposure parameters data was collected retrospectively, for consecutive adult patients from 2 examination rooms for the period of four months. A total of 150 patients were involved and six different procedures were performed in the two centers.

2.1. Entrance Skin Dose estimation (ESD)

The term ESD refers to the absorbed dose to air at the center of the x-ray beam. The exposure to the skin of the patient during the procedure can be measured directly or estimated by a calculation to exposure factors used from the formula below:

$$ESD[mGy] = C(kV/FSD)^2 * (mAs/mm.AI) \quad (1)$$

Where C is constant and is equal to 0.2775 and mm. Al is the filtration thickness. Entrance Skin Dose was calculated by the use of Mathematical expression above incorporated into excels spreadsheet. Data analysis of exposure parameters was conducted with statistical software to determine mean value and 3rd percentiles (75^{th}) of entrance skin dose value (Samaila and Bello, 2021a).

3. Results and Discussions

The mean statistical distribution of exposure parameter, patients' age, entrance skin dose and diagnostic reference level logged for each patient during the procedure was shown in table 1 & 2. The comparison of entrance skin dose value was also tabulated in table 3.

Table 1. Mean exposure parameters, ESD and DRLs in SMH

Radiological Procedure	Age (year)	kV	mAs	FFD (cm)	FSD (cm)	ESD (mGy)	DRLs (75thpercentile)
Leg AP	33.00	64.15	18.30	100.00	87.85	1.09	1.22
Leg Lat	41.00	62.40	18.00	100.00	91.09	0.94	0.99
Foot AP	35.00	60.44	17.56	100.56	88.30	0.78	0.94
Foot Lat	34.00	60.60	17.60	100.30	86.17	0.83	1.00
Ankle AP & Lat	51.00	64.23	18.77	100.00	87.69	0.94	1.12

Table 2. Mean exposure parameters, ESD and DRLs in FMC

Radiological Procedure	Age (year)	kV	mAs	FFD (cm)	FSD (cm)	ESD (mGy)	DRLs (75^{th}percentile)
Leg AP & Lat	43.00	64.59	5.32	106.29	94.41	0.22	0.27
Foot AP & Lat	41.50	63.71	5.00	91.93	79.64	0.30	0.36
Ankle AP & Lat	27.00	60.00	6.40	98.00	91.00	0.68	0.69

Table 3. Comparison of ESD with other Studies

CENTRE/Other Studies	Radiological Procedures					
	Leg AP	Leg Lat	Foot AP	Foot Lat	Ankle AP	Ankle

						Lat
SMH	1.09	0.94	0.78	0.83	0.94	0.94
FMC	0.22	0.22	0.30	0.30	0.68	0.68
Taha *et al.*, 2015	-	-	0.10	0.10	-	-
Iseh *et al*., 2020	-	-	-	-	-	-
Mohamed, 2010	-	-	0.12	0.14	0.17	0.12
Buhari and Bello, 2021b	1.27	-	-	-	-	-

4. Discussion

The use of diagnostic imaging in lower extremities continues to increase worldwide, and the field of foot, ankle and leg, is a particularly heavy user. Although strides have been made at reducing the radiation associated with various types of medical imaging, public concerns persist regarding the associated exposure to potentially harmful ionizing radiation. This study was performed to determine the radiation dose received by the skin's organ in lower extremities' procedures. Table 1: shows statistical distribution of age of different patients with average age ranging from 33 years to 51 years for each radiological procedure performed. It was observed from the table, that the highest kV and mAs given to the ankle procedure but highest ESD was found in leg procedure followed by Ankle. Similarly in table 2: Those underwent leg procedure has the highest age, and kV but ankle procedure recorded highest value of mAs, ESD, and DRLs. The results of this study were compared with those obtained by other scientific studies within and outside the country. The former studies showed different results in the dose received by patients. In table 3 the ESD obtained in all procedures in SMH is higher than that of FMC. The variation was due to the differences in exposure parameters.

The research conducted by Buhari and Bello (2021b) indicated that the result of leg procedure is justified, but reverse is the case, in foot procedure because the results obtained in this work is remarkably high compared to the work of (Taha *et al.*, 2015 and Mohamed, 2010). Similarly in ankle procedure, the results of this work were well compared with the results of (Mohamed, 2010) but found to be remarkably high. In addition, the significance of dose optimization and justifications during conventional x-ray imaging must be considered. Finally, in this research, it was found that radiation dose [ESD] for the entire examinations were higher in some procedure compared to the in-country and outside-country studies but lower than 1m Gy standard in Nigeria. This study should help investigators discover the critical parts of radiation protection in patients at radiology departments that many investigators have not been able to explore.

5. Conclusion

Findings presented in this research work indicates that radiation dose received by patients undergoing lower extremities x-ray examination in SMH and FMC, Birnin Kebbi is not above 1mGy except in AP leg procedure performed in SMH. The maximum mean radiation dose (ESD) recorded is 1.09 mGy and 0.94 for leg and ankle respectively in SMH. In radiological exposure, a periodic dose assessment should be made to enhance the optimization of the radiation protection of the patients and to deliver minimum dose to the examinations. Further investigations are

recommended with a greater number of patients, more modalities and using more methods for the assessment of entrance skin dose for comparison.

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